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***Radiocarbon dates and technological change in salt production at the site of
Zhongba in the Three Gorges, China***

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INTRODUCTION

The site of Zhongba 中壩, in Zhong Xian 忠縣 County, Chongqing 重慶 Municipality (FIG. 1), is one of the most significant sites to have been excavated during the decade-long Three Gorges Dam salvage archaeology effort – a project that has been sponsored by the Chinese government and involves

archaeological teams from around the country. Three principal vessel types--jiandigang 尖底缸, jiandibei 尖底杯, and huandiguan 圜底罐--each from a distinct depositional context, comprise the most significant component of the archaeological remains from the site. As discussed below, they overwhelmingly dominate the ceramic assemblage at the site, and they most likely represent tools used in the production of salt from brine available in the vicinity (Chen 2003; Flad 2004; Li 2003; Sun and Zeng 1999; Sun 2003; Zeng 2003). Recent chemical analyses of residues in the clay matrix of these vessels support this interpretation (Flad et al. 2005; Zhu et al. 2003).

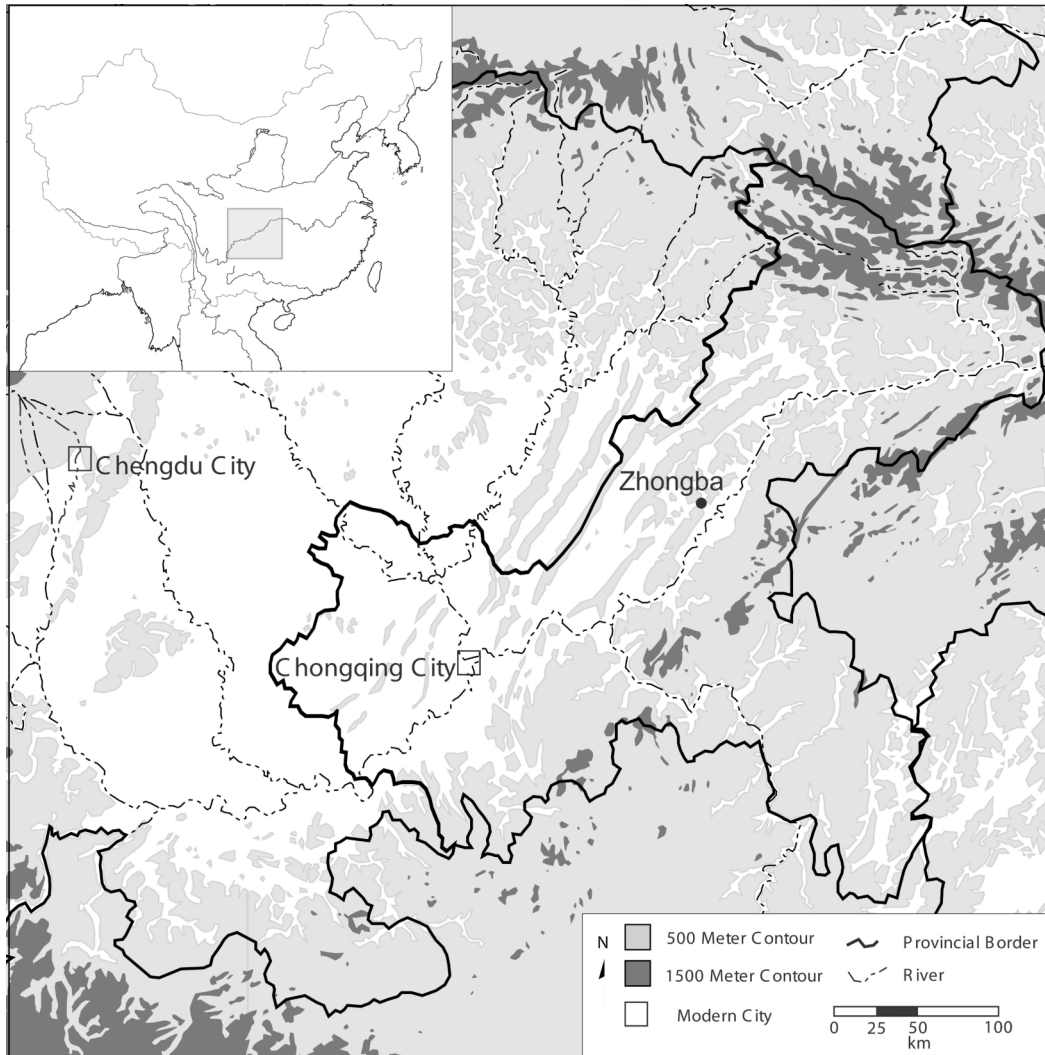


Figure 1. Location of Zhongba in Chongqing, China.

One extremely important question is whether they are chronologically distinct and indicate different technologies, or whether they served as different components of a single technological system. If they do represent chronologically distinct technologies, did they seamlessly develop out of each other, or were the

periods of activity at the site separated from one another? The issues can be addressed by a detailed absolute chronology based on a sequence of radiocarbon dates. As discussed below, a series of radiocarbon dates from the site show that the salt-production technologies represented by these different types of briquetage are chronologically distinct and represent two instances of technological change that occurred in the salt production of the eastern Sichuan Basin.

The chronological research presented here is vital for placing the material from Zhongba in a larger regional social context. By both demonstrating that these remains represent three distinct stages in the technology of salt production at Zhongba and placing these stages within an absolute chronology for the region, the data discussed here allow us to understand the relationship between changes in salt production at Zhongba and regional developments in social organization within the Three Gorges and surrounding areas. Although research on social change in the area during the late Neolithic and Bronze Age is still in its infancy, the past decade of research has created a general understanding. The over 2000 years contemporary with the stratigraphic sequence at Zhongba saw the development of strong long-distance networks connecting communities in the Three Gorges together and with societies even more distant. Throughout this era, the settlements known from recent archaeological research within the Three Gorges were all relatively small in size, but during the late second millennium BC, and particularly in the first millennium, links developed between these

communities and urban settlements in the Chengdu Plain to the west and in the Middle Yangzi River region. We believe that transitions in salt production at Zhongba relate to broader changes in the social networks connecting sites throughout this region.

ZHONGBA AND SALT PRODUCTION

After receiving preliminary assessments in the 1950s and again in 1987, Zhongba was excavated continuously from 1997 to 2003 by a team from the Sichuan Institute of Cultural Relics and Archaeology under the direction of Sun Zhibin (Beijing 1991; Ba 1992; Sichuan et al. 2001, 2003, 2007). As part of this effort, from 1999 to 2001, a UCLA-Peking University joint project team conducted a detailed excavation of one 10 x 10 meter sample-area (officially labeled 99ZZDT0202; hereafter referred to as Unit DT0202) at the site with a focus on two principal aims: evaluating the evidence for early salt production at the site, and improving our understanding of the chronological changes at the site--and by extrapolation, in the region around Zhong Xian--so as to comprehend the connections between salt production and environmental and social changes (Chen 2004; Flad 2004; Sun Zhibin 2003). Zhongba is particularly well suited to an exploration of the latter issue because of the long period of activity and the deep cultural deposits. The cultural levels in Unit DT0202, which is not even the deepest unit excavated at the site, extend to nearly ten meters below the modern

surface of the site. Nearly all of these accumulations consist of densely packed cultural debris, mostly pottery, that may have been related to the production of salt during the period when the site was occupied.

Zhong Xian--and more specifically the Ganjing 甘井 river valley where Zhongba is located--is historically known to have been an important region for salt production since at least the early centuries A.D (Liu Weiguo 2002, 2003). The *Huayangguozhi* 華陽國志 (Record of the states south of Mt. Hua), by Chang Qu 常璩 (ca. A.D. 291-361), the earliest local gazetteer in China¹, recorded the existence of salt administration offices in Linjiang County, currently known as Zhong Xian:

Linjiang County. It is four hundred *li* from the eastern part of Zhi County, and it abuts Juren County to the east. Salt administration offices were located in the Jian and Tu River valleys and the subsistence of all people in the county relied on them. Some wealthy families also had salt wells on their own estates. 臨江縣枳東四百里接朐忍。有鹽官，在監涂二溪，一群所仰。其門亦家有鹽井。 (*Huayangguozhi* “Bazhi,” pp. 30)

The Jian River is now known as the Ganjing River and the Tu River is the Ruxi River, which runs parallel to the Ganjing River to the north. The *Shuijingzhu* 水經注, an extensive commentary by Li Daoyuan 酈道元 (d. A.D. 527) on the

Shuijing 水經 (Book of Waterways), a 3rd Century B.C. geographical work on rivers, also contains descriptions of salt production and administration in the Ganjing River valley based, in part, on quotations from the *Huayangguozhi*:

“Downstream to the east, the Yangzi River reached southern Linjiang County, which had been Jianjiang County in the Wangmang period. It is stated in the *Huayangguozhi*: ‘[Linjiang] County is located four hundred *li* from the eastern part of Zhi County and it abuts Juren County to the east. Salt administration offices are established in the county. The Yanjing [Salt well] River enters the county in the north, and some salt wells and workshops exist [along it]. The [Yanjing] river enters into the Yangzi River.’

江水又東逕臨江縣南，王莽之監江縣也。《華陽記》曰：「縣在枳東四百里，東接朐忍。縣有鹽官，自縣北入鹽井溪，有鹽井營戶，溪水沿注江。」”(Shuijingzhu “Jiangshui Yi,” Vol. 33: 2801-2802)

The reasons why this area was so important for salt production during historical eras relate to the geological and ecological characteristics of the Ganjing and Tu River valleys. Both of these tributary streams cut across a geological fold known as the Dachi-Ganjing anticline which comprises the edge of the Wan Xian salt basin. In this area, salt strata were deposited during the

Triassic epoch an inland sea evaporated in the Sichuan Basin area (Li 2006). The resulting salt deposits made the Sichuan region an important source of salt historically, but much of this salt is deeply buried in the central part of the basin. One the basin edges, however, in areas like Zhong Xian, the salt deposits were closer to the surface and brine which was formed by ground water flowing through these deposits was naturally effluent in some places. The earliest exploitation of brine sources near Zhongba probably occurred at these natural salt springs. Zhongba was a particularly suitable place for the development of salt production due to the accessibility of salt, and also the availability of other resources nearby. Clay for producing ceramic vessels used in the brine boiling activities was present immediately across the Ganjing River from the Zhongba site. These clay sources were used up to recent years by local potters. Furthermore, the Ganjing River, which cut through rather narrow defiles up river from Zhongba, opened up at the site making the location appropriate for a moderate sized community and making agricultural fields, hunting areas, and fishing localities more easily accessible than in the more precipitous parts of the river further upstream.

Scholars have various opinions on the exact date of the establishment of salt administration offices in this area; however, based on archaeological remains, historical accounts, and local legends, most agree that the establishment was no later than the Eastern Han. One legend gives the credit for first drilling salt wells

in the Ganjing and Tujing Valleys to Yang Zhen 楊震, a famous officer in the Eastern Han period. According to the *Houhanshu* 後漢書, the official history of the latter Han, Yang Zhen was not a local officer in this area, but rather the governor of Jingzhou Prefecture. A stele at *Jingshenmiao* 井神廟, a temple that is located in the countryside near Zhongxian dedicated to Yang Zhen, who is worshipped as the salt deity (Sun Hua 2003), describes his discovery of salt brine on his way to Jingzhou, which is located downstream along the Yangzi River to the east. Most of the few salt administration offices that were established during the Han Dynasty were located in areas that already had history of salt production, and the Linjiang administration is no exception.

Subsequently, salt production continued into much more recent periods in Zhong Xian and remained an important economic activity in the small town adjacent to Zhongba into the 20th Century. Local villagers recall production of salt as recently as the 1960s. The salt was produced from naturally effluent brine, which was made more easily accessible by the construction of wells, one of which remains today in the immediate vicinity of Zhongba. This relatively recent salt production involved large iron evaporation pans and was based on processes introduced during the Han period.

ZHONGBA *BRIQUETAGE*

Archaeological remains at Zhongba demonstrate pre-Han periods of salt production in the area. In particular, dense accumulations of pottery sherds suggest that salt production goes back into prehistoric times. The pottery deposition patterns known from pottery-based salt production industries in other ancient cultures as well as in modern ethnographic contexts elsewhere in the world--in places as far a-field as England (Brisay 1975), Louisiana (Brown 1980, 1996), Poland (Bukowski 1985), Coastal China (Fang Hui 2004; Li et al. 2003), Niger (Gouletquer 1975), Japan (Kitabayashi 1969; Kondo 1975, 1984), Central America (McKillop 2002; Parsons 2001), Central Europe (Riehm 1961; Weller 2004), and the Philippines (Yankowski 2004)--resemble those discovered at Zhongba (Chen 2003).

At many of such locales, the remains of the salt production pottery, often referred to as *briquetage*, are deposited adjacent to the locus of salt production, forming mounds or thick middens of fragmented pottery. The ceramic assemblages recovered from these contexts are extremely homogeneous and comprise mostly vessels and objects that differ markedly from local household ceramics. There is a great deal of consistency, cross-culturally in the forms that salt production vessels take. In many of these contexts, both ancient and modern, pointed bottom vessels are used as brine storage containers or salt-cake molds. Rounded-bottom vessels are used in several well-documented contexts as brine-

boiling vessels. The specific salt production techniques used in various ethnographic and historic contexts vary in their details. The variety of salt production techniques have been discussed in detail in many contexts². Unfortunately, few studies of ethnographic, historic, or archaeological cases of salt production have discussed the organization of salt production and its role in society to any degree (see Flad 2003, 2004). Instead, most archaeological studies have focused on reconstructing production processes, and this only after salt production can be surmised as a primary site function based on evidence such as homogeneous ceramic assemblages.

Of course, there are other industrial-scale activities that might result in homogeneous ceramic deposits. In order to demonstrate with some confidence association with a particular production process, the functional role of the dominant ceramics should be investigated, and other lines of evidence, including associated features and residue analysis should be conducted. In comparing vessel morphology, use-wear, and associated features, we rely on ethnographic and archaeological analogies with other contexts where salt production is more securely identified. Chemical analyses of residues are more direct means to assess vessel function.

The earliest levels at Zhongba have quite heterogeneous ceramic assemblages, but soon thereafter, the deposits become very homogeneous. This homogeneity alone, however, does not securely identify Zhongba as a salt

production locality. Starting with the stratum in which the Zhongba remains become homogeneous, each level is dominated by a single type of vessel, and although there are three distinct dominant vessel forms, each is similar to *briquetage* found in one or more of the world regions mentioned above.

The three *briquetage* forms at Zhongba each occurs in massive quantities and dominate the assemblage to the point of nearly complete homogeneity. In unit DT0202 alone, we recovered 202,713 fragments of pottery. A total of 134,265 of these sherds were recovered by screening soil with 6 mm mesh from a series of 1 X 1 meter sample areas, one of which was excavated in each stratum. Due to the massive quantity of pottery at the site, only large rim sherds and other unusual diagnostic vessel fragments were saved from the soil outside these sample areas. The vast majority of the systematically-collected representative pottery sample recovered from each of the sample areas comprises one of three types of *briquetage* known from the site (see Chen 2003; Flad 2004, 2007; Li 2003; Sun and Zeng 1999; Sun 2003; Zeng 2003 for extensive discussions of these ceramics). Of the 134,265 sherds from the sample area, only 7787 (approximately 6%) were not fragments of one of the three *briquetage* types.

As we will discuss further below, the three *briquetage* types were chronologically distinct. The earliest type is the *huabian jiandigang* 花邊尖底缸 (pointed bottom vat with scalloped-rim). On account of the large size (ca. 40 cm in rim diameter), thin walls, and evidently large numbers of these vessels,

thousands of sherds have been excavated (32,295 sherds in sample areas from 16 strata). Attempts at refitting these vessels have been futile due to the vast numbers and homogeneous nature of the sherds. They have cord marking on their external surfaces, thick, coarse, pointed bases, and relatively straight, thickened rims with wavy impressions (FIG. 2). Once these vats started being produced, which, as shown below, started between 2500-2000 B.C., they comprise 92% of the total assemblage from the various levels in which they are found (Levels 68-49b, non-inclusive). In the earliest level (68) they comprise only 27%, and in the latest levels in which they are found they comprise 73% (Level 52a) and 14% (Level 50), but in the rest of the levels with sample areas containing jiandigang fragments they range from 83% (Level 52b) to 99% (Level 62) of the collection. All but three of these levels contain more than 93% jiandigang. These vessels are quite similar in overall shape and size to ceramics used in coastal Japan for salt production (Kitabayashi 1969; Kondo 1975, 1984). They may have functioned as brine storage containers.

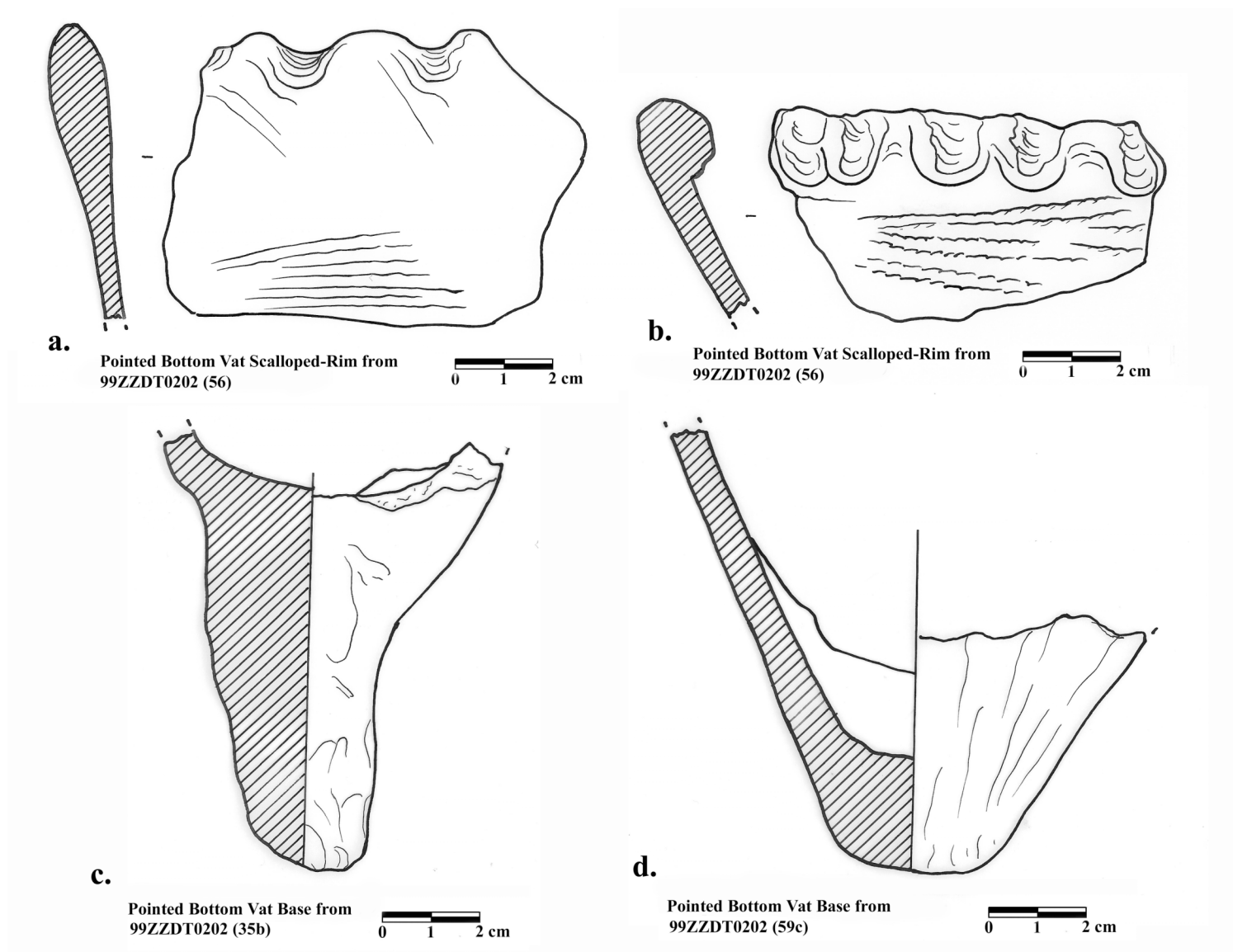


Figure 2. Fragments of pointed bottom vats (*jiandigang*) from DT0202.

The next kind of vessel thought to be related to salt production dominates the pottery collection in only two levels--50 and 49b. This is the pointed bottom cup (*jiandibei*) (FIG. 3). A variety of types of pointed-bottom cups have been discovered at the site, but only the short type depicted in Figure 3a occurs in massive quantities in Unit DT0202. Other sites in the region, however, have large amounts of the taller type depicted in Figure 3b. In level 50 at Zhongba, *jiandibei* sherds comprise 2177 of the 3961 sherds in the sample area (55%). The remainder of the sherds includes a variety of vessel types. The next level, 49b, is much more homogeneous, with *jiandibei* sherds comprising 43,644 of the 45,443 (96%) total vessel fragments. Pointed bottom cups may have been molds for the production of salt cakes. They are similar to “augets” used in Central European and Mesopotamian salt production (Potts 1984; Riehm 1961).

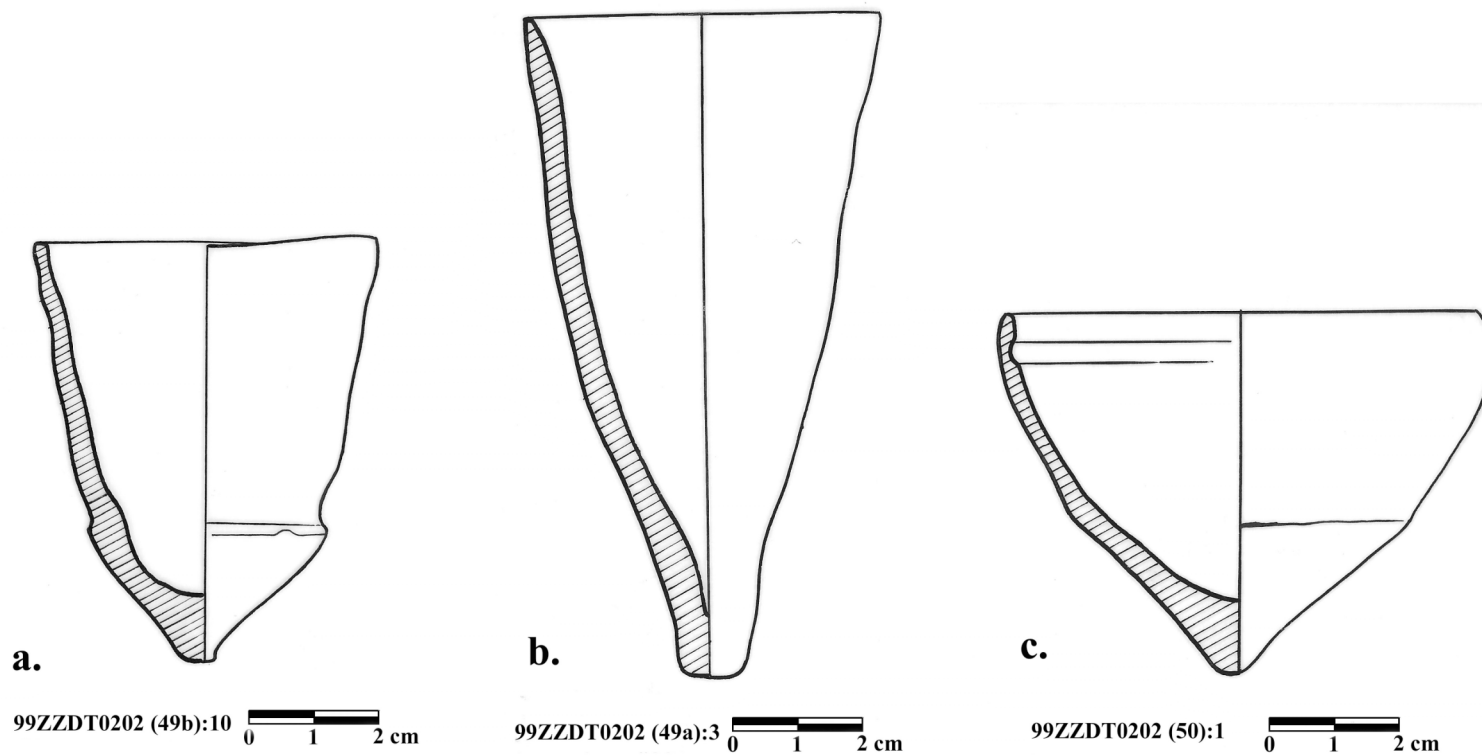


Figure 3. Pointed bottom cups (*jiandibei*) from DT0202.

Latest and most numerous among the briquetage types at Zhongba are rounded-bottom jarlets (*huandiguan*). There are three main chronologically distinct types of this vessel: large scalloped-rim (FIG. 4a), smaller scalloped-rim (FIG. 4b), and without scalloping (FIG. 4c). The former type only occurs in the earliest levels with *huandiguan* whereas the latter two types comprise the majority of *huandiguan* at Zhongba. Many millions of *huandiguan* sherds have been unearthed at the site, including 48,170 in the 1 X 1 meter sample areas of DT0202 alone. These sherds come from the sample areas in 21 stratigraphic levels and represent an estimated 1360 vessels. Extrapolated to the entire unit, these sherds represent over 55,000 *huandiguan* in the area of DT0202, an area that should be a relatively representative 9 X 9 meter area of the core of the production zone. The same estimates suggest that individual strata in this area contained between 130 and 10,111 vessels (Flad 2004, 2007). With the exception of the first level with *huandiguan* fragments in the sample area (Level 47) in which 55% of the ceramics are *huandiguan*, the remaining 20 levels range between 85% and 99.5% homogeneous. In only four of these levels do *huandiguan* comprise less than 94% of the ceramics. These rounded-bottom vessels are very similar in form to salt-production pottery from contexts around the world -- from the Maya sphere (McKillop 2002), to Africa (Gouletquer 1975), to the Philippines (Yankowski 2004).

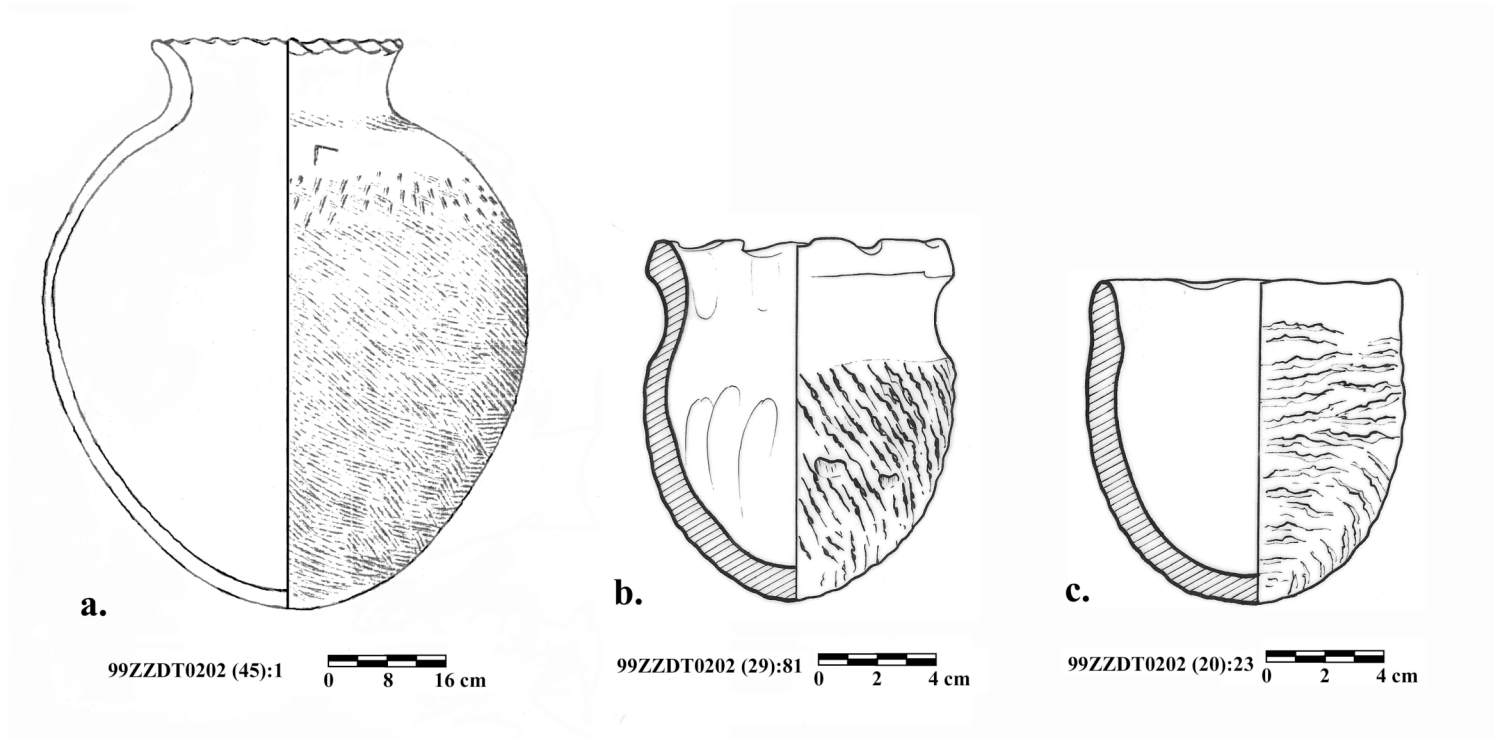


Figure 4. Rounded bottom jarlets (*huandiguan*) from DT0202.

This assemblage homogeneity in these various strata together with the strong morphological similarity between the vessels and salt-production pottery from elsewhere in the world, are the two principal reasons why these have been identified as *briquetage* types (Chen 2003; Sun 2008). This conclusion has been supported by XRD and SEM analyses that have compared trace elements in residues found in *huandiguan* to the locally available brine and examined the presence of sodium and chloride in the walls of *huandiguan* vessels (Flad et al. 2005; Zhu et al. 2003). The similarities between residues and the brine on the one hand, and the higher density of sodium and chloride on the inside of these vessels both support the hypothesis that these were primarily salt production vessels.

Despite the homogeneity within levels, three very distinct vessel types have been discussed from the Zhongba remains. These vessels are very different in overall size and shape. They could not conceivably have been used for identical functions. Nevertheless, all three general forms--*jiandigang*, *jiandibei*, and *huandiguan*--share similar depositional contexts and resemble *briquetage* from other regions. The vats may have been used for storage of brine, or large amounts of salt. It is also conceivable that they were vats employed in the production of fish-sauce or some sort of preserved food products (Flad 2005). The cups were much smaller, and discovered in huge numbers. These may have been used effectively as molds to dry wet salt and create relatively uniform cones of salt. The *huandiguan* jarlets are most similar to vessels known from ethnographic

contexts in Niger and the Philippines (Gouletquer 1975; Yankowski 2004). In these cases similar vessels were placed over fires and used to boil brine and produce large salt cakes. If the three types were used contemporaneously, it is conceivable that they were all part of a single, multi-stage salt production process. Alternatively, if they were not contemporaneous, the differences suggest that drastic changes occurred in the salt production process at Zhongba. As intimated above, the different types do come from distinct excavation strata. Although this suggests chronological difference, there is no way to know how much time passed between the creation of these different strata without some means of establishing an absolute chronology for the different levels.

CHRONOLOGICAL ANALYSIS

In fact, a clear understanding of the absolute chronology of this site and of the surrounding region bears directly on the overall effort to understand the various environmental, social, and industrial changes that took place over time at Zhongba. Recent archaeological work has greatly expanded our understanding of the prehistory of the 500-km stretch of the Yangzi valley between Chongqing City and the Three Gorges (eg. Chongqing and Chongqing 2001, 2002, 2006, 2007; Guowuyan and Guojia 2003, 2005, 2006, 2007). The excavation of numerous sites with long stratigraphic sequences has advanced our understanding of the ceramic chronology for this region. Scholars have begun to compare these sequences with those from other adjacent areas where the absolute dates are more

firmly established, such as the Middle Yangzi region of Hubei and Hunan, and the Sichuan Basin (eg. Chengdu Shi Kaogu Yanjiusuo et al. 2000; Jiang and Wang 1998; Jiang Zhanghua 2002; Sun Hua 2000). The stratigraphic relationships between different assemblages are quite clear from excavation, and a detailed relative chronology of the region is now in place. In order to more firmly situate the archaeological study of prehistoric Chongqing in the extra-regional developmental processes in early China, we are in need of a benchmark set of absolute dates with which we can compare the emerging ceramic sequence. The dates discussed here provide that benchmark, but at the same time, as the discussion below demonstrates, the previously established ceramic chronology has provided a very important corrective for the sequence of dates from Zhongba. In addition to illuminating the process of technological change at the site of Zhongba, therefore, chronological work discussed here should also be taken as a cautionary tale that demonstrates the need to evaluate both ceramic seriation and radiocarbon dates in relation to one another.

Beginning in December 2001, the collaborative team working at Zhongba embarked on a concerted effort at radiocarbon dating. By testing samples from the full sequence of cultural levels exposed in DT0202, we hoped to produce a series of dates that would demonstrate whether the site was continuously occupied, or whether there were significant periods during which the site--or at least the area of the site under investigation--was abandoned. Such a long series of dates would

also help establish the absolute chronology of the site with some degree of certainty. The excavations of Unit DT0202 at Zhongba only produced 19 samples of charred organic materials, however, coming from Levels, 33, 35b, 41, 45, 46, 47, 50, 51b, 52b, 53, 54, 55b, 59, 59c, 60, and 64. These samples are not exhaustively representative of the levels excavated. Furthermore, only about half of these samples were in good condition. It was fortunate, therefore, that the excavations of Unit DT0202 also produced abundant faunal remains in every stratum.

All of the bones from non-feature loci--totaling over 129,000 specimens--have been subjected to preliminary zooarchaeological analysis (Flad 2004, 2005). These “non-feature loci” are the superimposed strata that were formed anthropogenically by discard and trampling of trash (including animal bones), the unintentional transfer of soil from off-site by human movement, and alluviation from a nearby stream. The most significant components of these strata are the fragments of *briquetage* themselves, animal bones, and soil that was intentionally laid down across the production area in order to create workshop floors. The remaining portions of the floors themselves and pits of various kinds that were created around the site are also important archaeological contexts, but the non-feature loci provide a continuous record of activity and are therefore preferable for chronological analysis. The bones from these strata are adducible to

radiocarbon testing and can be used to produce a complete radiocarbon profile of Zhongba.

Twenty-seven bone fragments were selected for AMS C-14 analysis at the Peking University Carbon 14 laboratory. The selection of samples occurred in two stages. The first batch of samples was selected from seven well-preserved, important cultural levels. The uppermost of these was Level 18, a thick level with abundant pottery and the latest complete level excavated in Unit DT0202. Based on the ceramics and other artifacts from this stratum and those immediately above, Level 18 is presumed to date to the Warring States period (traditional dates 475-221 B.C.)³. The next level selected in this first batch was Level 29, a level full of scalloped-rim, rounded bottom jarlets, possibly a type of vessel used in salt production during the late period of occupation at the site. This level is presumably Springs and Autumns period in date (traditional dates 770-476 B.C.). The third level selected was Level 38b, a thick ashy level with abundant ceramic and faunal remains. The preliminary ceramic chronology places this level into Late Western Zhou (ca. 1045-771 B.C.). An earlier Western Zhou level is Level 46. This was the latest level in which we recovered significant amounts of pointed bottom cups, the second most recent kind of presumed salt-making ceramics at Zhongba. From the time period when pointed bottom cups were most abundant, thought to be contemporary with the Shang period (ca. 1600-1045 B.C.), we selected bone samples from Level 49b. Lastly, we selected samples from two

Neolithic Levels, 56 and 68. Level 68 is the lowermost level excavated in Unit DT0202, although other parts of the Zhongba site have even earlier occupations. Level 56, on the other hand, is one of the latest culturally Neolithic levels and associated with extremely abundant large pottery vats--the vessel class that may have been related to salt production during this early period of occupation.

The bones from each of the above levels were selected by several of the authors and associates at Peking University, including Wu Xiaohong, Rowan Flad, Pan Yan, and Qin Ling. Many of the bones recovered from the site have already begun to fossilize but a sufficient number of well-preserved bones were still amenable to analysis. Between four and eight samples were selected from each level to provide a sufficient number in case certain specimens were found inappropriate. Two specimens from each of these seven levels were eventually selected for AMS dating. A second batch of sample was then selected to fill in the gaps between the above levels.

The second batch of specimens includes bones from Levels 22, 32, 33, 37, 43, 48, 49a, 50, 52a, 53a, 58a, 64, and 65b. One sample was selected from each of these thirteen levels. These either fill in significant gaps in the first batch or represent levels particularly important to our understanding of the chronological profile of the Zhongba remains. The latter category includes the samples from Levels 48, 49, 50, 52a and 53a. These levels lie at the stratigraphic juncture where pointed bottom vats (Levels 52a and below), pointed bottom cups (Levels 48

through 51) and rounded bottom jarlets (Levels 47 and above), come together. If there were significant gaps in the occupation of the site, and if these gaps coincided with the shifts in pottery types, the radiocarbon dates from these levels should be most instructive in illuminating this situation.

In addition to the 27 bone samples submitted to AMS dating at Peking University, an additional five samples of charcoal were submitted to the same lab for normal C-14 dating. These samples come from Levels 46, 50 and 64 (three samples from level 46 were selected due to their unusually good preservation). In total, therefore, 32 radiocarbon samples have been analyzed by the C-14 lab at Peking University. The AMS analysis was performed by Liu Kexin according to the following procedures; they are also described in greater detail elsewhere (Guo et al. 2000; Guo et al. 2001; Wu et al. 2000; Yuan et al. 2000).

The protocol for AMS dating of bone samples involves a multi-stage operation from pretreatment through the final calibration of the radiocarbon dates. The bone samples are pretreated and bone gelatin is extracted. Surface pollutants are first physically removed from the bone samples. The samples are then crushed and placed in distilled water, where they are washed repeatedly by ultrasonic cleaning until the distilled water remains colorless. After an acid/alkali/acid preparation sequence, the samples settle in a neutral state, and are hydrolyzed in a pH 3 HCl acid solution with a constant temperature. This process removes

insoluble fractions, and further lyophilization separates out white gelatin for analysis.

After oxygenization, multiple combustions of the gelatin purify the samples, resulting in pure carbon dioxide, which is then collected. Using iron powder as a catalyst and hydrogen as a reduction agent at a temperature of 540 °C, the carbon dioxide is reduced to carbon, and subsequently made into graphite. Following this, the measurement of the graphite samples by accelerator mass spectrometry is taken at the AMS laboratory in the Institute for Heavy Ion Physics, Peking University using a cluster-array static accelerator. The spectrometry produces dates corrected by isotopic fractionation. Initially, this produces uncalibrated dates given in BP years before 1950 with an assumed C-14 half-life of 5568 years. For the Zhongba samples, these dates can be seen in Table 1. Finally, we calibrate the dates using the dendrochronologically based OxCal version 3.5 (Bronk Ramsey 2000), which incorporates the INTCAL98 calibration curve (Stuiver et al. 1998).

The protocol for the conventional C-14 samples used in this study involves sample pretreatment, benzene production, measurement of C-14 isotope amounts, and calibration. The pretreatment process begins with a careful selection of samples and the removal of surface impurities. The samples are soaked in distilled water and washed multiple times by ultrasonic cleaning until the distilled

water remains colorless. After an acid/alkali/acid sequence of rinses to remove impurities, the samples are returned to a neutral state and dried for analysis.

After pretreatment, the samples are placed in the reactor and fused with calcium in a vacuum. The samples remain at a constant temperature of 500 °C for 30 minutes and then at 700 °C for another 30 minutes, all the while in a protective vacuum. After another 2 hours at a constant temperature of 1000 °C, CaC_2 is synthesized. The CaC_2 , under the affect of water, hydrolyzes to become acetylene. After multiple rounds of purification, this acetylene is returned to the reactor where, under the influence of catalysts, benzene is synthesized. Five ml of this fabricated benzene are combined with 30 mg of an illuminating agent in a measuring flask. The benzene must be quantified exactly. It sits for one week and then the sample is processed. We use an American PACKARD Tri-carb 2770 TR/SL Liquid Scintillation Analyzer to carry out the measurement of the C-14 isotope amounts. The calibration procedure is the same as that used for the AMS samples discussed above.

In addition to the analysis performed at Peking University, five samples from identical contexts were submitted to Beta Analytic Laboratory in Miami, FL in order to verify the absolute chronology of several loci that include particularly important elements in the changing Zhongba material culture. The samples that were submitted to Beta Analytic include bones from Levels 68, 56, 49b, 29, and 18. Samples from Levels 68 (Beta 181183) and 18 (Beta181179) were chosen

because these levels represent the earliest and latest contexts in the excavated area respectively. The dates from these two loci are therefore extremely important because they bracket the time period of salt-production activity at the site.

The other samples were selected based on the preliminary results from the Peking laboratory. Level 56 (Beta181182) was selected because it was the latest level in the cluster of radiocarbon dates that mark the Middle to Late Neolithic period at the site. Level 49b (sample Beta181181) is the last level in the second cluster of radiocarbon dates from the Peking University analysis and marks a particularly significant phase in terms of the material culture recovered from the site. During this phase the briquetage used at the site changed dramatically to *jiandibei*--the pointed bottom cups mentioned above and depicted in Figure 3. Finally, a sample was taken from Level 29 (Beta181180) around the middle of the last phase of activity at the site in order to further verify the dates in that part of the chronology.

These five samples were selected from same collection of bones that were used by the Peking University laboratory. Ideally the same bone would have been used for the analysis done at each laboratory but this was not possible because we were only permitted to conduct destructive analysis on small fragments of bone and the preparation techniques employed by the Peking University lab necessitated that we use different bone fragments for the analysis in the separate labs. The bones from each bag not used in the Peking University analysis were

transported to the U.S. after permission was obtained by the Chinese National Bureau of Cultural Relics, and they were then sent to Beta Analytic.

RESULTS

The calibrated radiocarbon dates that resulted from the analyses discussed above range from as early as 2470 B.C. to as recent as 200 B.C. (See Table 1). Not surprisingly, perhaps, these dates generally confirm the time period from which the levels excavated at Zhongba were previously assumed to date. The Neolithic levels in Unit DT0202 are not the earliest Neolithic remains from Zhongba. Neither is the earliest Neolithic period present at Zhongba the earliest in the Ganjing River valley: considerably earlier remains have been found at the site of Shaopengzui 哨棚嘴 at the confluence of the Ganjing and Yangzi Rivers (Beijing Daxue Kaogu Wenboyuan Sanxia Kaogudui et al. 2001; Li 1995; Wang 1996) and at other nearby sites (Flad and Chen 2006). Nevertheless, the cluster of radiocarbon dates from the Peking University analysis of samples from Levels 56 through 68, seen on the left hand side of Figure 5, clearly represents the dates of the middle to final phase of the so-called Neolithic period at the site. The calibrated dates for these levels range from as early as 2470 B.C. to approximately 1750 B.C. in level 56. Level 56, the latest level dated within this cluster, and the thick Levels 57a and 59c, were all located in the southwestern corner of Unit DT0202, where the cultural levels slope severely to the southwest

(FIG. 6). This slope marks the edge of the Zhongba mound at the time when these deposits were formed. Excavations in 2002-2003 in the unit immediately to the west of DT0202, namely DT0102 (FIG. 7) demonstrated that this slope was not the edge of a large pit but instead was where the slope down to the river course was located. The ceramics from these levels are very abundant and dominated by the deep-belly, pointed-bottom, scalloped-rim vats (*jiandigang*) discussed above. These are not the latest levels with sherds of such vats, which are also found in considerable numbers up to Level 53a, and occasionally in even later levels. However, the absolute dates of the period between Level 56 and level 50 are somewhat enigmatic due to some odd results from the radiocarbon analysis. We will return to this issue shortly.

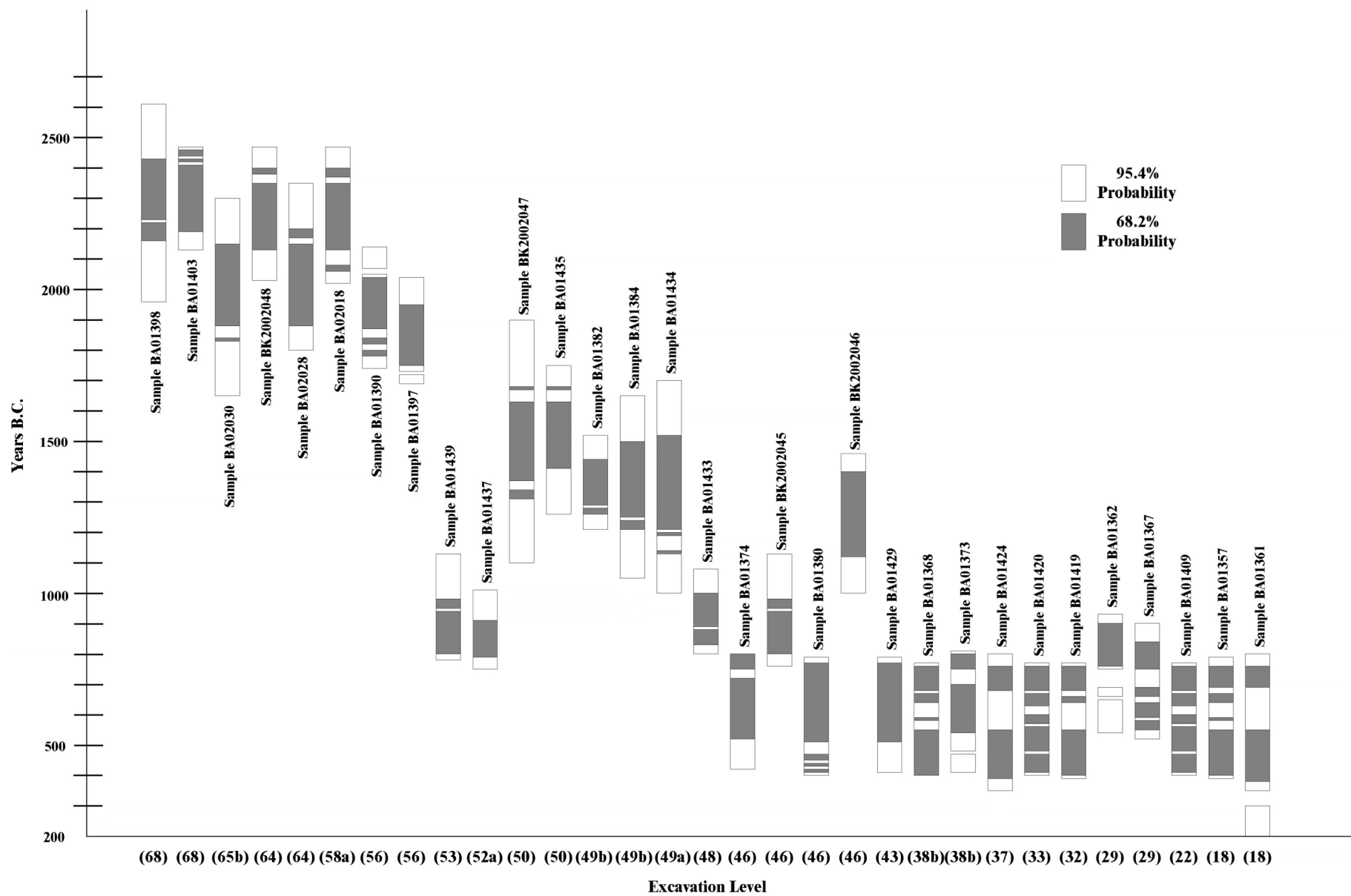


Figure 5. Radiocarbon profile for AMS and standard samples from DT0202 analyzed by the Peking University laboratory.

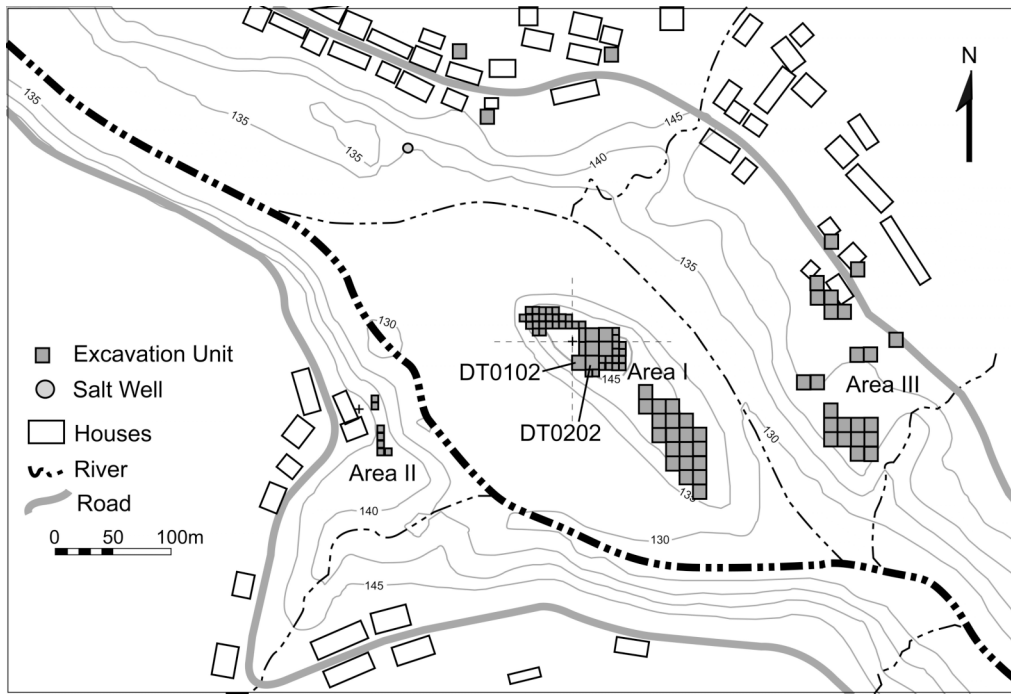


Figure 7. Topographic map of the site of Zhongba with the location of excavation unit DT0202 and associated units.

The second cluster of dates apparent in Figure 5 is associated with Levels 50, 49a, and 49b, shown in the east baulk profile from DT0202 in Figure 8. This period seems to date from about 1650 B.C. in Level 50 to 1200 B.C. in Level 49a. The majority⁴ of the first standard deviation of probability for the date of Level 50 fits between 1630 and 1370 B.C., confirmed by both a bone AMS sample (BA01435) and a conventionally analyzed carbonized wood C-14 sample (BK2002047)⁵. The calibrated dates of levels 49a and 49b are ca. 1520-1210 B.C. according to the 1 σ range of the Peking University results. As discussed

further below, the Beta Analytic results for this part of the sequence suggest an even later date. These levels are those in which the pointed bottom cups discussed above were found in large numbers. The traditional use of the term “Shang Period” to refer to such remains seems to be technically correct, although it should not be taken to imply that the area around Zhongba was ever part of the Shang realm. These dates are clearly separated from the dates from the earlier pointed-bottom vat levels by a hundred years or more. We cannot say, however, that the site, or even the part of the site represented by Unit DT0202, was abandoned during this period, however, since the only radiocarbon dates from Levels 50-56 are problematic, and these levels have a sequence of changing pottery assemblages. Nevertheless, it does seem evident that the period when pointed-bottom cups were used at a large scale and the period when the large, pointed-bottom vats were predominant are not contemporaneous and are, in fact, two chronologically distinct phases in the development of salt production technology at Zhongba. The stratigraphic superposition of these two vessel types did not result from the nearly contemporary deposition of dissimilar vessels in multiple events, but indeed represents a real chronological difference.

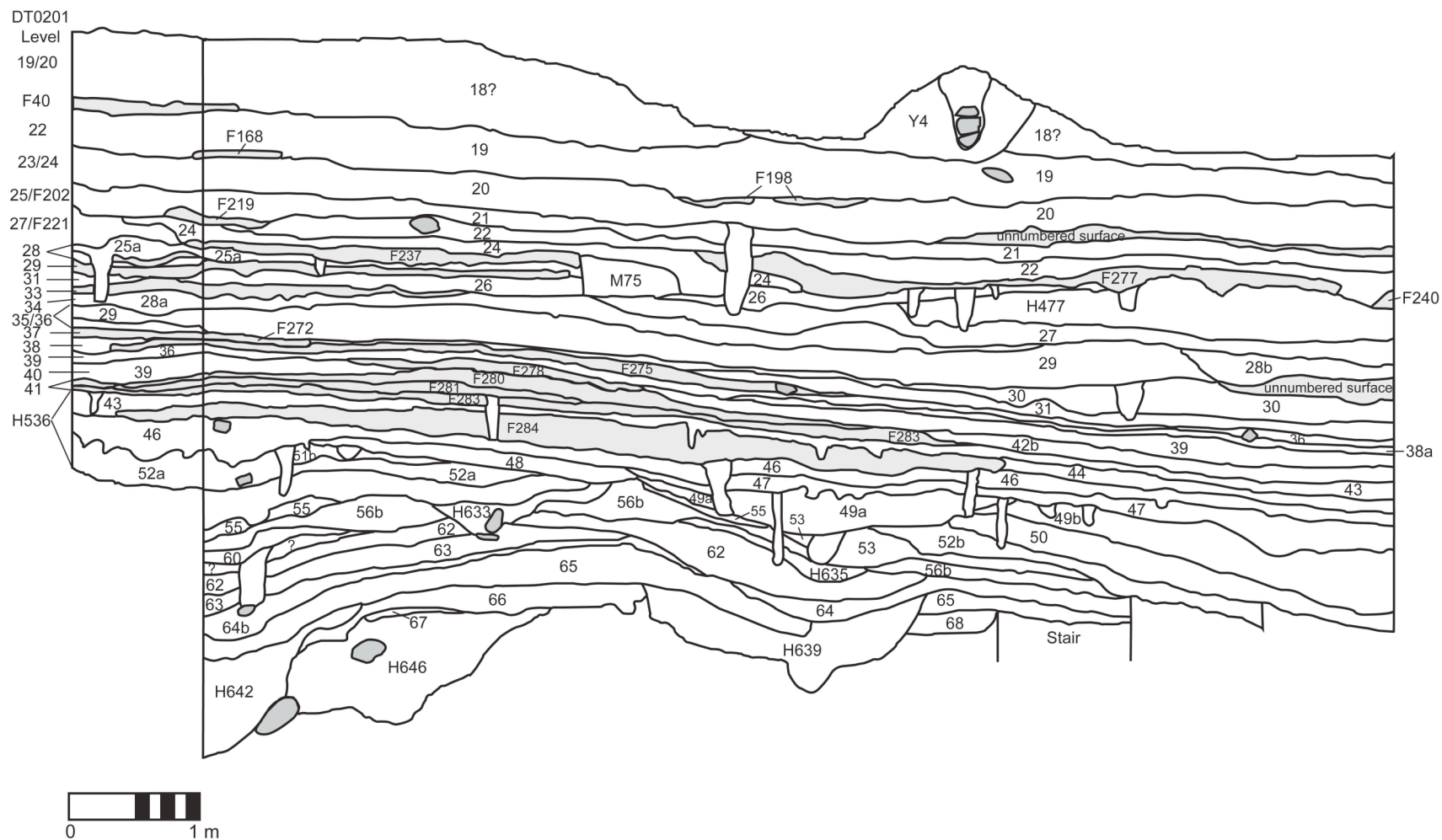


Figure 8. East baulk profile of DT0202.

The chronological gap between this “Shang Period” phase and the next phase of activity is even clearer. It is possible that this even represents a hiatus in activity in the area of Unit DT0202, and perhaps at the site as a whole, but the radiocarbon data cannot provide conclusive tests of this hypothesis. In Figure 5, the dates of levels from Level 48 and later all post-date 1080 B.C. at the very earliest and most likely date after 1000 B.C. The hiatus between Level 49a and Level 48 may well be in excess of one hundred years, but the 2 σ data provided in Table 1 show that it is also conceivable that there was no break in occupation. The ceramic remains from these this sequence of levels shows that significant transitions occurred at this time. For example, the first levels of activity during this third phase actually pre-date the rounded-bottom jarlets discussed above. The earliest type of these vessels is a large one with deep scalloping that only begins to occur in large numbers around Level 38b. This would place the date of the origin of large-scale use of this kind of vessel at around 800 B.C. at the earliest. Massive scale production and use of smaller rounded-bottom jarlets that are more standardized in size and shape does not seem to occur until slightly later stratigraphically, but it is clear from the radiocarbon profile in Figure 5 that the dates from levels after Level 46 cluster within the range from 800 to 350 B.C. This time period is commonly referred to as the “Eastern Zhou” in discussions of the ceramics of the region, but as we should expect, the dates do not exactly correlate with the “Eastern Zhou” period discussed by Chinese historians. In general, it seems that the previous assumptions about the general chronology of this period have been basically correct.

The results from the Beta Analytic analyses further support this chronological reconstruction. Three of the five samples produced results extremely similar to those from the Peking University lab. These include Samples BA1390 and Beta181182, both of which came from Level 59, Samples BA1367 and Beta181180 from Level 29, and Samples BA1357 and Beta 181179 from Level 18. As the data in Table 2 and Figure 9 show, the dates from these samples are quite similar in terms of both 1 σ and 2 σ calibrated results. Perhaps most significant among these data is the 1 σ result for Beta181179, which shows a strong probability that the date for Level 18 is between 400-420 B.C. The several dates from the Peking University laboratory from this Level had wider ranges (see TABLE 1 and FIG. 5). This strongly supports the contention that activity at Zhongba ceased or changed drastically in the early fourth century B.C., just preceding the time of the Qin conquest of the area in 316 B.C.

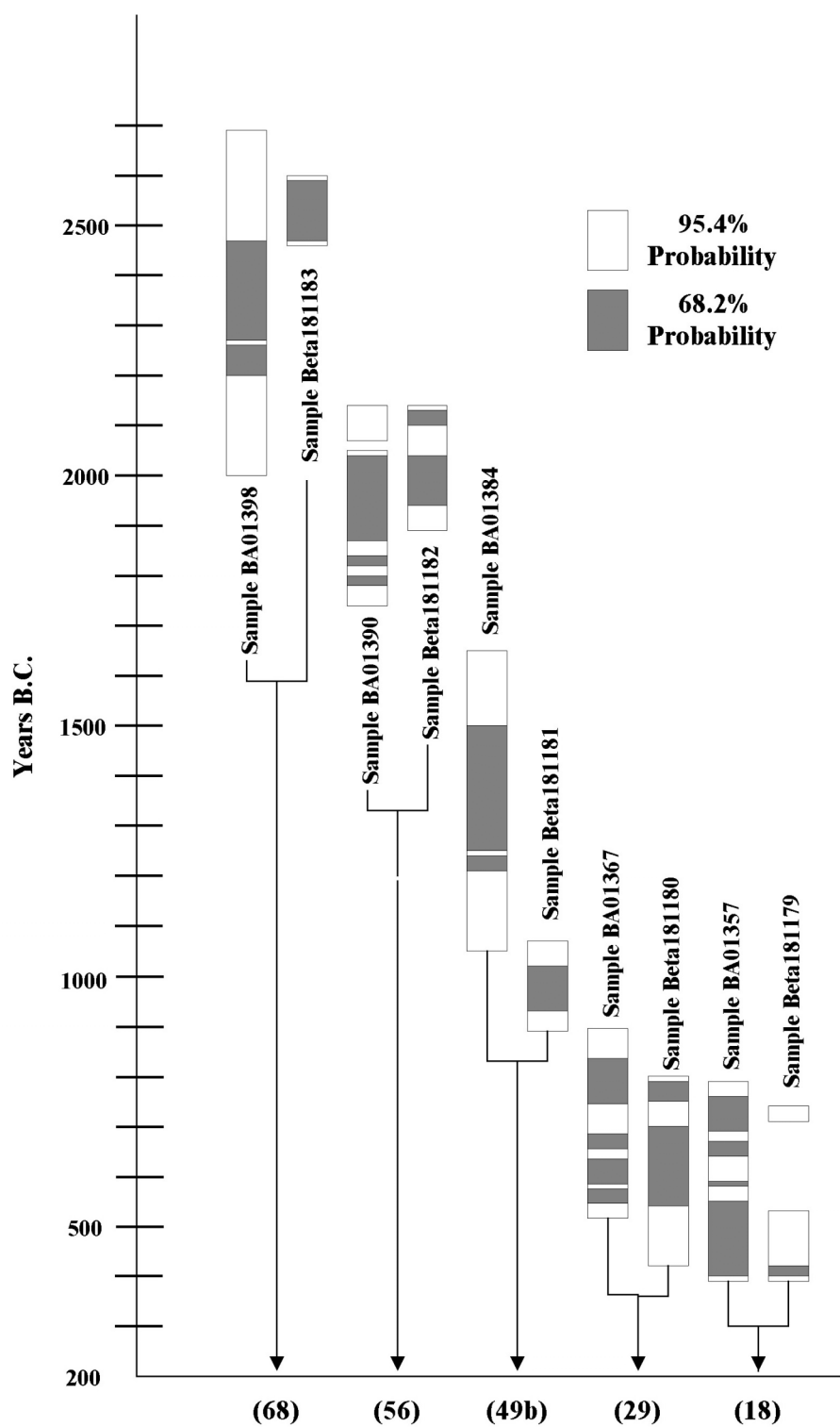


Figure 9. Comparison of the dates from Beta Analytic and samples from identical contexts analyzed by Peking University.

Two of the five Beta Analytic dates are somewhat different from those determined by the Peking University laboratory. The dates provided for Beta181183 (Level 68) are slightly earlier than the time span that was most probable for sample BA1398. Nevertheless, the 2σ calibrations of both samples are compatible. Based on these results it seems clear that the earliest level represented in Unit DT0202 at Zhongba dates to around 2500 B.C.

The second problematic set of samples comes from Level 49b. Two samples from this level were analyzed by Peking University, both of which provided very similar results (See Table 1: Samples BA01382 and BA 01384). As previously mentioned, the 1σ calibrations for these two samples were 1440-1260 B.C. and 1500-1210 B.C. respectively. The Beta laboratory results for a sample from the same locus, and exactly the same context as BA01382, produced quite different results. This sample (Beta181181) has a 68.2% probability of dating to between 1010 and 920 B.C. and a 95% probability of dating to 1060-880. These dates do not even overlap with the 2σ calibration of BA01382 (1520-1210 B.C.) and only barely overlap with the latest possible dates according to the 2σ calibration of BA01384 (1650-1050 B.C.). Considering the fact that the dates for Level 49a (BA01434) and Level 48 (BA01433) are more similar to those of Beta181181 we believe that this bone fragment might have been discovered out of place in Level 49b. The conditions that may have resulted in the contamination of Level 49b and the occurrence of this later bone fragment in an earlier level are further elaborated below.

Despite these two differences between the of results from the Peking University and Beta Analytic labs, the overall C-14 profile of the samples is, in general, both internally consistent and fits the expected absolute dates for the

cultural remains. These results show us that the activities at Zhongba, as represented by the excavations in Unit DT0202, can be separated into three distinct phases that separately involve the three different vessel types discussed above. They are also extremely useful in anchoring the ceramic-based relative dating scheme that has recently begun to emerge from excavations at a large number of sites in the Three Gorges area.

Anomalies

There are, however, several anomalies in the sequence of dates from the Peking University lab that must be further discussed. In particular, wood charcoal sample BK2002046 from Level 46 and bone AMS samples BA01437 and BA01439 from Levels 52a and 53 do not fit seamlessly a stratigraphy-based radiocarbon profile.

Let us first discuss the wood charcoal sample BK2002046. We were able to obtain several dates for Level 46 since that level's charcoal samples were well preserved, and bone samples were analyzed as well. One of the three wood charcoal samples did not produce a radiocarbon date; but the other two did, as did two bone samples. Three of these samples, bone samples BA01374 and BA01380 and charcoal sample BK2002045, produced rather consistent results. Both of the bone samples date to the period between 400 and 800 B.C. with over 95% probability, and to ca. 510–770 B.C. with over 60% probability. The charcoal sample produced slightly earlier dates, ca. 800-940 B.C. with 62.5 % probability and over 95% likely to be between 760 and 1130 B.C. The fourth sample, however, wood charcoal sample BK2002046, produced a date that is over 68% likely to fall between 1120 and 1400 B.C., and 95.4% likely to fall between 1000

and 1460 B.C. This date would be clearly within the range of the dates in the second phase of activity documented at the site (Levels 50, 49a and 49b)--yet this carbon sample was excavated from within the Level 46 matrix and thus belongs stratigraphically within the third phase. It is possible that the sample was corrupted, or that its actual date falls outside the range of likely dates. Another strong possibility is that the wood from which this sample came is much older than the date of the level in which it was discovered.

At this point, a general comment concerning the differences between carbonized wood samples and bone samples is in order. Four of the five carbonized wood samples analyzed produced radiocarbon dates. All of them were from levels in which a bone AMS date was also produced. One sample, BK2002046 from level 46 seems anomalous, as discussed above. Two of the other three, BK2002045 from Level 46 and BK2002048 from Level 64, produced dates that, while basically consistent with the bone samples from the same level, were nevertheless noticeably earlier. The former has already been discussed. The Level 64 specimen most likely dates to 2030-2470 B.C. while the bone sample from this level had a range of 1700-2350 B.C. There is considerable overlap between these dates. The peaks of their probability curves intersect between 2130 B.C. and 2200 B.C. Even so, it is interesting that these three wood carbon samples all seem to date slightly earlier than their bone counterparts. This phenomenon quite possibly reflects the “old wood” effect of dating parts of trees that are closer to the core and therefore older than the time when the tree is cut down. By contrast, the fourth wood charcoal sample, BK2002047 from Level 50, coincides very neatly with its bone counterpart: it dates to 1100-1900 B.C., and the bone sample from this level has a 95.4% probability of also dating within this time

frame (1260-1750 B.C.); both share an over 63% probability of dating to ca. 1370-1630 B.C.

The second set of aberrant dates is more peculiar. Both samples from between Levels 50 and 56--stratigraphically well within the first of our three phases of activity--produced radiocarbon dates that considerably post-date the second phase and seem to fit at the beginning of the third phase. Sample BA01439, from Level 53, produced a date that, with 95.4% likelihood, falls between 780 and 1130 B.C., and is 63.4% likely to date to 800-940 B.C. Likewise, sample BA01437 from Level 52a produced a date that is 95.4% likely to date between 750 and 1010 B.C. Why are these dates, the only ones we have from the gap between Levels 50 and 56, so late? Can these anomalies be explained away as corrupt samples or excavation errors?

It is possible that the specimens used for Levels 52a and 53 were somehow corrupted during excavation or during analysis. This solution has already been proposed for the problematic Beta Analytic date from Level 49b (Beta181181). It is conceivable that significant amounts of post-depositional disturbance, such as the digging holes that are then filled in or bioturbation including rodent action, might have brought bones from a much *later* period into *earlier* cultural levels in this part of the site stratigraphy. Although this is possible, we would argue that a more parsimonious solution exists that both explains these anomalous dates which further supports the notion that a different kind of post-depositional disturbance may have been responsible for the presence of specimen Beta181181 in Level 49b.

In fact, significant post-depositional disturbance is suggested by indications that several strata seem to have been redeposited out of chronological order in

part of DT0202. This situation is not clearly evident in the stratigraphy itself, but the anomalies in the C-14 profile are also seen in the ceramics recovered from DT0202. When compared with other units at the site, Levels 52a and 53 are out of sequence in DT0202. According to the seriation of ceramics in the collections from various strata, levels 44-49a, 52a, and 53 should post date levels 49b-52b, which, in turn, are later than the lowermost levels 54-68. The stratigraphic confusion relates to the position and depositional processes particular to the levels above and below the so-called “Shang period” that comprise the levels between 49b and 52b. As seen in the north baulk profile depicted in figure 10, Level 52a was exposed along the north side of Unit DT0202 directly beneath Level 46. Across the entire northern half of the unit this level was completely covered with holes, some as deep as 50 cm. The function of these holes is still unclear but it is possible that they are the traces of some sort of scaffolding constructed during or slightly after the second period of activity at the site, when pointed bottom cups were in use. As shown in Figures 6 and 8, the levels stratigraphically superior to Levels 52A and 53, but below Levels 46 and 47, were limited to the southern parts of the unit where the earlier levels slope steeply downward toward the south and west. During the period of pointed bottom cup use, waste, including broken pottery, was disposed of off the southern bank of Zhongba into the channel of the Ganjing River filling in the slope.

Based on the analysis of pottery, it seems that the levels between 49b and 52b (not including Level 52a) were moved to this area from somewhere else after level 53 had been laid down. They may even have been laid down in reverse chronological order, though in general, they are roughly contemporaneous. As the slope was filled in, the northern part of Unit DT0202 remained at essentially the

same elevation. Consequently this area was made level during this period. This site formation process would explain how some strata that significantly predate levels 48 and 47 were deposited above Levels 52A and 53. If we readjust the sequence of archaeological levels according to the ceramic chronology we see that the radiocarbon profile no longer contains the anomalous dates (see FIG. 11).

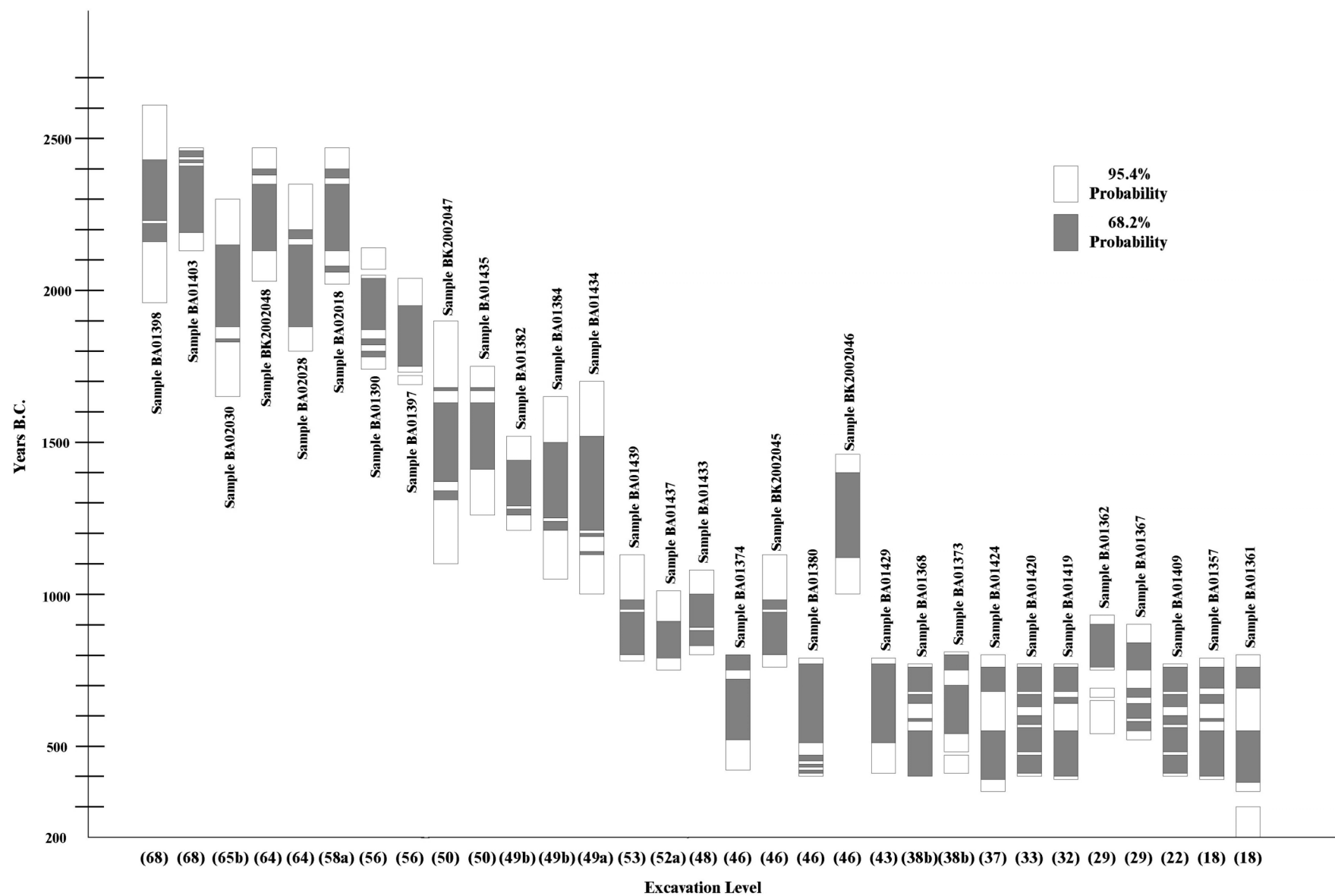


Figure 11. Radiocarbon profile for Peking University AMS dates in sequence according to stratigraphy adjusted based on ceramic analysis.

CONCLUSION

The results from 32 radiocarbon samples analyzed by the Peking University C-14 lab and five additional samples examined by Beta Analytic have produced a clear absolute chronology for the site of Zhongba and for the Three Gorges region of the Yangzi River drainage in Central China. These results have set a chronological base line for future work in the region and are a critical element of the effort to firmly establish the relationship between specialized salt production at Zhongba and the development of complex societies in both the Middle Yangzi River Valley and the Sichuan Basin.

These chronological data also demonstrate that the long-term development of salt production technology at Zhongba was not a seamless process but instead involved at least three significant transitions in production technique. The first technique used at the site, the primary remains of which are large vats possibly used in the storage of brine stopped being practiced sometime in the later part of the first half of the second millennium B.C. Soon thereafter a new production technique emerged, possibly immediately replacing the first, which involved small cups that may have been primarily used as cakes for salt molds. A third technology, based primarily on the use of rounded-bottom jarlets that may have been used to boil brine, emerged gradually in the first millennium B.C. and developed into a large-scale salt production industry. This technology persisted until near the end of the Bronze Age when it was replaced by iron-pan based brine

boiling--a technique that then continued, without fundamentally changing, until the 20th century.

The transitions in salt production technology at Zhongba do not seem to have been associated with whole-scale replacements of the material-culture but are instead one component of a gradually changing cultural repertoire that was affected most directly by technological innovations in a particular type of specialized activity--namely salt manufacture. These technological changes were one component of social changes occurring in the Three Gorges region during the second and first millennia BC. The exact nature of these changes is yet to be worked out, as extensive archaeological investigations of the region have only occurred recently. These recent investigations have included work on both nearby sites, and localities across the larger region.

Zhongba was not the only site in the Ganjing River valley, and the investigation of nearby sites provides some information on the local social environment. A cluster of sites is known from the mouth of the Ganjing River, where it meets the Yangzi. These sites include the Late Neolithic locality of Shaopengzui (Beijing et al. 2001, 2006), and the first millennium sites of Wazhadi (Beijing and Zhong Xian 2003) and Yajiao (Beijing and Chongqing 2003; Beijing et al. 2007). Excavations at Shaopengzui and Wazhadi both uncovered deposits associated with small settlements, while Yajiao is primarily a Late Bronze Age and Han period cemetery. The Shaopengzui remains suggest a

small-village that may have been associated with the relatively small-scale salt exploitation that was going on at Zhongba.

The change from this first phase of salt production, which employed jiandigang vats, to the second, associated with jiandibei cups, probably coincided with a ramping up of salt production in response to increasing demand from communities spread across a broader region. This new phase occurred in the second millennium BC, roughly contemporaneously with dramatic changes in the scale of social complexity in the Chengdu Plain of the Sichuan Basin associated with the site of Sanxingdui. Interregional stimuli probably played a role in the technological transformation seen at Zhongba.

The shift from the second to the third phase of production at Zhongba was probably even more closely associated with larger-scale political and social changes in the broader region. During the period when huandiguan jars were used for salt production, a gradual ramping up of production is clearly evident (see Flad 2007 for a discussion of this evidence). The Wazhadi site dates to the early part of this phase, and may reflect a period when the Zhongba locality was still being exploited by individuals residing elsewhere. As the scale of production increased, however, Zhongba probably became increasingly the center of specialized production activity. From the Yajiao cemetery we see evidence that, by the latter half of the first millennium BC, some people in the Zhongba area were associated with the powerful state of Chu down river in the Middle Yangzi.

Perhaps salt, or salted products were, a primary trade item sent from the Zhongba area to Chu during this period of increasing interstate rivalry and large-scale geopolitical maneuvering.

The full nature of the relationships among changes in salt production and other transitions at Zhongba are beyond the scope of this paper but future discussions should be able to explore this issue effectively given both the clear chronology and the evidence for technological innovations that are presented here. Nuanced understanding of historical and social processes must rely on well developed chronologies, and these are only possible through a rigorous examination of all available evidence, including radiometric dates, stratigraphic relationships, and an understanding of stylistic changes in material culture.

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Tables:

Table 1: Results of radiocarbon analysis conducted at the C-14 laboratory of Peking University. Sample numbers reflect the sequence of specimen analysis and the material – BA for AMS dating of bone material and BK for standard dating of charcoal. Locus numbers are strata from excavation unit DT0202

Sample #	Sample material	Locus	Field Catalogue Number	Uncalibrated Date b.p.	Calibrated date B.C. (68.2% probability)	Calibrated date B.C. (95.4% probability)
BA01398	Bone	68	FCN 3582-1	3880 ±90	2470-2270 (56.4%) 2260-2200 (11.8%)	2650-2000 (95.4%)
BA01403	Bone	68	FCN 3582-6	3840 ±60	2460-2440 (1.0%) 2430-2420 (1.9%) 2410-2190 (65.3%)	2470-2130 (95.4%)
BA02030	Bone	65b	FCN 3498	3640 ±100	2150-1880 (67.3%) 1840-1830 (0.9%)	2300-1650 (95.4%)
BK2002048	Wood Charcoal	64	FCN 3320	3800 ±70	2400-2380 (3.1%) 2350-2130 (65.1%)	2470-2030 (95.4%)
BA02028	Bone	64	FCN 3329	3660 ±100	2200-2170 (4.5%) 2150-1880 (63.7%)	2350-1700 (95.4%)
BA02018	Bone	58a	FCN 3142	3800 ±80	2400-2370 (4.5%) 2350-2130 (61.0%)	2470-2020 (95.4%)

					2080-2060 (2.7%)	
BA01390	Bone	56	FCN 2958-1	3590 ±60	2040-1870 (62.4%) 1840-1820 (3.7%) 1800-1780 (2.1%)	2140-2070 (7.6%) 2050-1740 (87.8%)
BA01397	Bone	56	FCN 2975-4	3540 ±60	1950-1750 (68.2%)	2040-1730 (93.1%) 1720-1690 (2.3%)
BA01439	Bone	53	FCN 2842	2730 ±80	980-950 (4.8%) 940-800 (63.4%)	1130-780 (95.4%)
BA01437	Bone	52a	FCN 2699	2680 ±70	910-790 (68.2%)	1010-750 (95.4%)
BK2002047	Wood Charcoal	50	FCN 2658	3210 ±120	1680-1670 (1.5%) 1630-1370 (63.4%) 1340-1310 (3.3%)	1900-1100 (95.4%)
BA01435	Bone	50	FCN 2675	3240 ±100	1680-1670 (1.7%) 1630-1410 (66.5%)	1750-1260 (95.4%)
BA01382	Bone	49b	FCN 2613-1	3100 ±60	1440-1290 (64.4%) 1280-1260 (3.8%)	1520-1210 (95.4%)
BA01384	Bone	49b	FCN 2613-3	3110 ±100	1500-1250 (65.8%) 1240-1210 (2.4%)	1650-1050 (95.4%)
BA01434	Bone	49a	FCN 2728	3110 ±120	1520-1210 (66.4%) 1200-1190 (0.9%) 1140-1130 (0.9%)	1700-1000 (95.4%)
BA01433	Bone	48	FCN 2578	2780 ±60	1000-890 (48.6%) 880-830 (19.6%)	1080-800 (95.4%)
BK2002044	Wood	46	FCN 2505	No Result	N/A	N/A

	Charcoal					
BA01374	Bone	46	FCN 2513-1	2520 ±70	800-750 (12.2%) 720-520 (56.0%)	800-410 (95.4%)
BK2002045	Wood Charcoal	46	FCN 2514	2730 ±85	980-950 (5.7%) 940-800 (62.5%)	1130-760 (95.4%)
BA01380	Bone	46	FCN 2527-1	2480 ±80	770-510 (64.0%) 470-450 (2.0%) 440-430 (1.6%) 420-410 (0.7%)	790-400 (95.4%)
BK2002046	Wood Charcoal	46	FCN 2528	3025 ±90	1400-1120 (68.2%)	1460-1000 (95.4%)
BA01429	Bone	43	FCN 2379	2490 ±70	770-510 (68.2 %)	790-410 (95.4%)
BA01368	Bone	38b	FCN 2219-1	2450 ±60	760-680 (21.8%) 670-640 (6.3%) 590-580 (2.0%) 550-400 (38.0%)	770-400 (95.4%)
BA01373	Bone	38b	FCN 2275	2540 ±60	800-750 (17.2%) 700-540 (51.0%)	810-480 (90.3%) 470-410 (5.1%)
BA01424	Bone	37	FCN 2229	2390 ±70	760-680 (17.9%) 550-390 (50.3%)	800-350 (95.4%)
BA01420	Bone	33	FCN 2136	2460 ±60	760-680 (22.4%) 670-630 (8.8%) 600-570 (3.5%) 560-480 (21.0%)	770-400 (95.4%)

					470-410 (12.5%)	
BA01419	Bone	32	FCN 2094	2430 ±60	760-680 (20.8%) 660-640 (2.6%) 550-400 (44.8%)	770-390 (95.4%)
BA01362	Bone	29	FCN 0981-1	2640 ±60	900-760 (68.2%)	930-750 (84.3%) 690-660 (3.0%) 650-540 (8.1%)
BA01367	Bone	29	FCN 1082	2600 ±60	840-750 (46.7%) 690-660 (5.9%) 640-590 (10.9%) 580-550 (4.7%)	900-520 (95.4%)
BA01409	Bone	22	FCN 0643	2460 ±60	760-680 (22.4%) 670-630 (8.8%) 600-570 (3.5%) 560-480 (21.0%) 470-410 (12.5%)	770-400 (95.4%)
BA01357	Bone	18	FCN 0006	2430 ±80	760-680 (20.4%) 670-640 (5.4 %) 590-580 (1.7%) 550-400 (40.7%)	790-390 (95.4%)
BA01361	Bone	18	FCN 0104-2	2380 ±70	760-690 (15.7%) 550-380 (52.5%)	800-350 (93.1%) 300-200 (2.3%)

Table 2: Comparison of Peking University and Beta Analytic dates on bones from identical contexts.

Sample #	Sample material	Locus	Field Catalogue Number	Uncalibrated Date b.p.	Calibrated date B.C. (68.2% probability)	Calibrated date B.C. (95.4% probability)
BA01398	Bone	68	FCN 3582-1	3880 ±90	2470-2270 (56.4%) 2260-2200 (11.8%)	2650-2000 (95.4%)
Beta181183	Bone	68	FCN 3582-1	4010 ±40	2580-2470 (68%)	2600-2460 (95%)
BA01390	Bone	56	FCN 2958-1	3590 ±60	2040-1870 (62.4%) 1840-1820 (3.7%) 1800-1780 (2.1%)	2140-2070 (7.6%) 2050-1740 (87.8%)
Beta181182	Bone	56	FCN 2958-1	3640 ±50	2120-2100 (12%) 2040-1940 (56%)	2140-1890 (95%)
BA01384	Bone	49b	FCN 2613-3	3110 ±100	1500-1250 (65.8%) 1240-1210 (2.4%)	1650-1050 (95.4%)
Beta181181	Bone	49b	FCN 2613-3	2820 ±40	1010-920 (68%)	1060-880 (95%)
BA01367	Bone	29	FCN 1082	2600 ±60	840-750 (46.7%) 690-660 (5.9%) 640-590 (10.9%) 580-550 (4.7%)	900-520 (95.4%)
Beta181180	Bone	29	FCN 1082	2520 ±50	790-750 (13%) 700-540 (55%)	800-420 (95%)
BA01357	Bone	18	FCN 0006	2430 ±80	760-680 (20.4%) 670-640 (5.4 %) 590-580 (1.7%)	790-390 (95.4%)

					550-400 (40.7%)	
Beta181179	Bone	18	FCN 0006	2380 ±40	420-400 (68%)	740-710 (16.2%)
						530-390 (79.1%)

ENDNOTES

1. A detailed discussion of the origins of the *Huayangguozhi* and its various versions can be found in the preface of the *Huayangguozhi jiaobu tuzhu* 華陽國志校補圖注, annotated by Ren Naiqiang 任乃強.
2. In addition to the references cited previously which detail particular case studies, the Zhongba remains are discussed in comparison to recent global research on the material components of salt production in a forthcoming volume of the series *Salt Archaeology in China*, edited by LI Shuicheng and Lothar von FALKENHAUSEN, to be published by Science Press (Kexue chubanshe) in China with an expected publication date of 2009.
3. Typically, different phases in this sequence are referred to by the conventional terminology of Chinese archaeology. Phases are referred to as “Neolithic,” “Xia - Shang Period,” “Western Zhou Period,” “Springs and Autumns Period,” and “Warring States Period,” for example, even though none of these terms, except

the first, is applicable to the Chongqing area in a political sense; they can only serve as chronological markers. There is no reason, however, to pre-suppose that the shifts in political regimes in the Central Plains should be contemporaneous with transitions between phases in the region around Zhongba.

4. Over 63% of the 68.2% that comprises the 1σ probability fit within this time frame.

5. As shown in Table 1, the entire 1σ range for BA01435 includes 1680-1670 and 1630-1410 calB.C., whereas the 1σ range for BK2002047 includes 1680-1670, 1630-1370, and 1340-1310 calB.C.

ABSTRACT

The pre-historic chronology of the Three Gorges region along the Yangzi River in China has become the focus of significant archaeological research in the last decade. The site of Zhongba is one of the most significant sites among those recently studied. Thirty-two radiocarbon dates produced by the C-14 laboratory at Peking University, and five additional dates from the Beta Analytic laboratory in the United States show a clear chronological profile of the activity periods at the site of Zhongba. This radiocarbon profile clarifies two very important issues related to the prehistory of the Three Gorges region. The dates anchor an emerging ceramic-based relative chronology in a series of stratigraphically-located absolute dates. This article discusses these results and suggests

explanations for several anomalous dates. The sequence demonstrates the need to reassess radiocarbon sequences by means of ceramic seriation. The dates also demonstrate that three different vessel classes, which dominate the ceramic assemblage at Zhongba, and which are believed to have been used in salt production at the site, date to three chronologically distinct phases of activity. The differences among the three types suggest that they represent a sequence of technological changes in the process of salt production at the site.

KEYWORDS: radiocarbon, Three Gorges, technological change, Chinese archaeology, salt production